

**Y-12
OAK RIDGE
Y-12
PLANT**

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**USE OF THE NUCLEAR MATERIALS
IDENTIFICATION SYSTEM (NMIS)
FOR ENHANCED RECEIPT CONFIRMATION
MEASUREMENTS AT THE
OAK RIDGE Y-12 PLANT**

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ABSTRACT

The Nuclear Materials Identification System (NMIS) developed by the Instrumentation and Controls Division of the Oak Ridge National Laboratory and the Oak Ridge Y-12 Plant has been used at the Oak Ridge Y-12 plant to perform enhanced receipts confirmation measurements providing mass estimates on low mass HEU metal pieces in shipping containers. For this application, NMIS was used in its active mode with a small Cf source on one side of the shipping container and detectors on the other side. Second order correlation measurements with calibration standards were utilized to obtain the mass of HEU. This was the first use of NMIS for receipts at the Y-12 Plant. This was a cost-effective method for measuring the mass of receipts with as many as 64 items measured in one day. This paper describes the reasons for using the NMIS for this application. The measurement technique and evaluation of the measurement data for this application are also described.

INTRODUCTION

The Nuclear Materials Identification System (NMIS)¹, developed by the Oak Ridge National Laboratory (ORNL) and the Oak Ridge Y-12 Plant (Y-12), has been used for a variety of NMC&A applications at Y-12. The applications at Y-12 include: determination that training units did not contain fissile material, confirmation of receipts of weapons components, confirmation of highly enriched uranium (HEU) metal receipts, in-situ confirmation of weapons components in storage, and quantitative verification of declared uranium mass and enrichment of HEU metal in storage. Most previous implementations of the Nuclear Materials Identification System (NMIS) verified the declared identity of an inspected nuclear weapon component by comparing the signatures measured from the inspected component to a prototypical template of signatures measured from a component whose identity was already unambiguously known. This paper describes NMIS confirmation of fissile mass of HEU metal receipts in containers in 1998.

Operational problems at the Y-12 plant precluded the normal activity of unpacking and weighing the items in the required timeframe. To meet DOE Order requirements for receipt accountability measurements, and thus avoid an NMC&A finding, approval was granted by DOE Oak Ridge Operations Office to use NMIS as an interim "enhanced confirmation" measurement. This was to ensure that the HEU quantity was as declared by the shipper. The non-intrusive NMIS measurement did not require opening the shipping containers and alleviated contamination control concerns. The flexibility of the NMIS system permitted its use while no other non-destructive measurement techniques were acceptable or available for these measurements.

These confirmations were the first application of NMIS for quantitative measurement of the fissile mass of receipts while still in containers. The requirement was for the mass determination to be within 20% of the declared for these interim confirmations. The time constraints on the confirmation were such that the calibrations had to be developed and the confirmations completed in three consecutive days before Christmas holidays or the Y-12 Plant would have to bring workers in on holidays using methods that required removal of material from the containers at considerable expense and possibly compromising worker safety due to known contamination control concerns. For these configurations NMIS operated as an active neutron interrogation system using a small ^{252}Cf source ($\sim 1\text{ }\mu\text{g}$ or less) in an ionization chamber and scintillation detectors to acquire a variety of time correlation signatures.¹

METHODOLOGY

Two NMIS signatures were used in these confirmations: (1) the covariance between a detector and the source, and (2) the covariance between detectors. Various features of the NMIS signatures depend on the attributes of the fissile material. For these measurements, the source was located on one side of the container with an array of detectors on the opposite side, 180° around the container from the source. There were two HEU items in each container. A NMIS measurement was performed for each container at two heights which corresponded to the location of the parts. These heights were the same for all containers and most of the variations in the signature for items of the same mass were due to packaging variations.

A typical covariance between a detector and a source for the standard annular HEU casing for storage at Y-12 is given in Fig. 1. For this source-detector container configuration, time correlation of a detector signal with the source provides the data from a time-of-flight transmission measurement through the item under interrogation. The ^{252}Cf spontaneous fission in an ionization chamber provides a timed source of prompt gamma rays and neutrons. By time-of-flight the prompt neutrons and prompt gamma rays can be separated in time. Time correlated radiation from the source arrives at the detector in the following order: transmitted prompt gamma rays, scattered gamma rays, transmitted prompt neutrons, scattered neutrons (all from Cf fission), fission induced prompt gamma rays, and fission induced prompt neutrons, of course all with some overlap.

Time correlation measurements between pairs of detectors yield the distribution of correlated pairs namely gamma-gamma pairs, neutron-neutron pairs, and gamma-neutron pairs. A typical cross correlation between a pair of detectors is given in Fig. 2. The gamma-gamma correlations can easily be separated since they occur mainly at zero time delay since both gamma rays from fission arrive at the detectors nearly simultaneously. These covariances of detectors with the source and between pairs of detectors have a variety of features that can be used to characterize the item under interrogation since they depend on amount and configuration of fissile material.

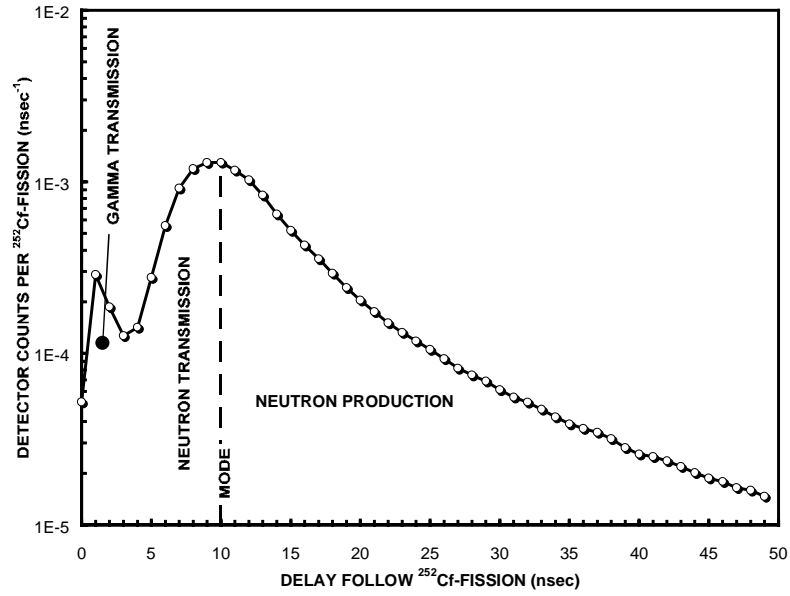


Fig 1. Covariance between the ^{252}Cf -source and one detector acquired during an active measurement of a uranium-metal casting.

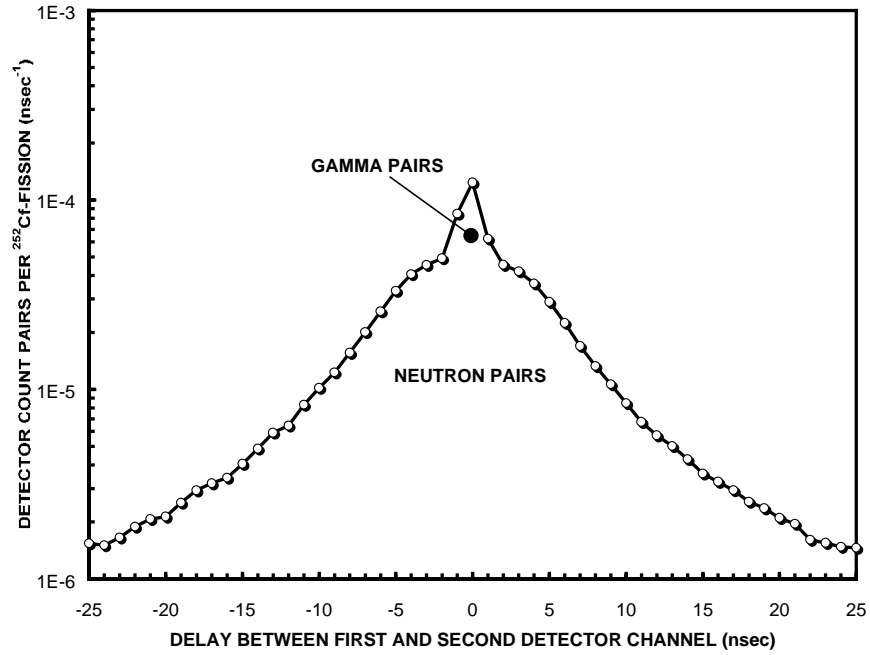


Fig 2. Covariance between two detectors acquired during an active measurement of a uranium-metal casting.

Because of the low mass of this HEU, most of the covariance between detectors was at zero time lag. Most of the time correlations at zero time are from coincident pairs of gamma rays from fission. Neutron-neutron pairs at time lag zero are small because of the varying velocity of neutrons from fission. The integral of the cross correlation around time lag zero provides essentially the number of gamma-gamma coincidence counts. This feature of this signature and the total number of transmitted gamma rays from the covariance between a detector and the source were the features that were used for these confirmations (Fig. 1). The transmitted gamma rays depend on the total mass and the gamma-gamma pairs depend on spontaneous fission gammas from the source (transmitted gamma pairs) and gamma rays from induced fission (induced gamma pairs) in the HEU. By dividing the gamma-gamma coincidence rate by the transmitted gamma rays, the effects of the container and variations in packaging were minimized. Three randomly selected items that spanned the declared mass variation were used as calibration standards. They were later verified by weighing and gamma ray spectrometry. The ratio of gamma pairs to transmitted gamma rays was linear with mass. This ratio as a function of mass was linearly fitted to obtain the calibration that was used to estimate the fissile mass for the other items to be confirmed.

RESULTS

These particular features of the covariances of the remaining HEU metal receipts were compared to the calibrations in order to estimate the HEU masses. These estimates were then compared to the declared mass. Comparisons of the NMIS HEU mass estimates for each container and their uncertainties with those declared are presented in Fig. 3 for the containers in the order (abscissa) that they were measured. The measurement agreement was deemed adequate to ensure that the material receipt quantity was as declared by the shipper. Because all these confirmations were performed at two fixed heights on all containers, the major portion of uncertainty results from uncertainty in the location of HEU in the containers. These confirmations were performed in a timely, cost-effective manner with as many as 64 items measured in one shift utilizing 4.5 min of data acquisition time per item. Facility operation was cost effectively enhanced by this use of NMIS.

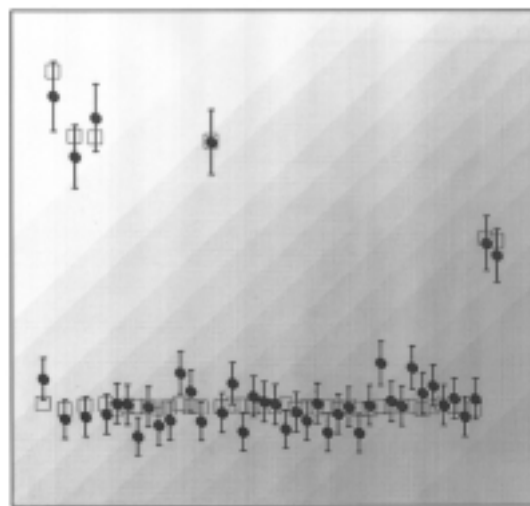


Fig. 3. Comparison of NMIS HEU Masses With Declared For Receipts.
(□ signifies declared, • signifies measured with its uncertainty.)

CONCLUSIONS

These NMIS measurements in 1998 were the first use of NMIS for fissile mass quantification. The accuracy was sufficient for this application and the Y-12 Plant confirmed all these receipts on a schedule that avoided a NMC&A finding. Increased operational costs for immediately opening the containers would have been significant and may have jeopardized worker safety. Considering the time constraints of three days to develop the calibrations and perform the measurements, the results were quite good and met the requirement. Subsequent measurements for other HEU reported in other papers^{3, 4} at this conference have demonstrated not only mass but enrichment measurements within ± 5 percent.

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